

# Current Situation of Water Pollution and Human Health in the Republic of Benin

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**Abstract-** Water is an essential element for humankind, animals, and plants. It is also an important element of the aquatic environment (the natural habitat of multiple species), where its quality plays a determining role in their protection and conservation. Unfortunately, the water quality of natural environments has worsened in the last decades. In Africa and particularly Benin, monitoring the quality of surface water is a very rare activity.

Water pollution in Benin has become a major public concern in recent times because it breeds poor environmental conditions which threaten the health of the people. To determine the effects of water pollution on the people in the Republic of Benin, some studies have been done before and we decided to conduct a review looking at the current situation of water pollution in Benin.

Towards the end of 1998, Benin began to place a high priority on environmental matters, particularly water-related issues. This is reflected in recent environmental policies, legislation, action plans and programs introduced by the Government. In all these programs, environmental monitoring activities, especially water quality aspects, are given strong consideration. With the creation of the General Directorate of Water (DG-Eau) as the central coordinating body for all water matters within the country, Benin has developed a mechanism that will monitor water quality adequately and will keep a record of all relevant environmental variables. New concept Integrated Water Resources Management adopted by the Government of Benin will improve all aspects of water use and conservation within the country if the political will and financial resources for its implementation to be sustained.

Finally, the review shows that the risk of water pollution exists and it is necessary to take measures of water treatment and sanitation to prevent the further degradation of water resources in Benin.

**Index Terms-** Water pollution, Human Health, IWRM, Benin

## I. INTRODUCTION

Water quality around the world constitutes a major concern for populations because not only it is a valuable resource but it is also necessary for our existence [1]. According to FAO, the global demand for fresh water is doubling every 21 years. Water

plays a vital role in the daily activities of humankind. It is an important element of both aquatic environments and the natural habitat of multiple species (fish, batrachians, birds, and mammals) [1].

From an ecological point of view, water is a vital resource for all living organisms, and at the same time, it is a habitat for aquatic organisms. In the early 1970s, it was thought that water quality, under which the efficiency of reproduction of aquatic organisms is highest, must be regarded as good water quality. But urbanization, anthropogenic activities in the floodplain, and other cropping activities affect water quality [2]. Societal activities interact with the environment for the provision of basic needs (food, shelter, and clothing) and in doing so, they contaminate the waters thus making them unhealthy for human consumption [3]. Unfortunately, human activities along river courses are capable of degrading the quality of these rivers.

The quality and quantity of available water supply intakes have positive and negative implications on the health status of communities and societies. Over 500,000 people die daily worldwide to water-borne diseases [4]. It is also estimated that about 4 million children under five years old die annually in developing countries because of water-borne diseases [5]. Worst still 2.3 billion people worldwide have mortality and morbidity associated with water-related ailments [6, 7]. Increased population, geological factors, rapid urbanization, agricultural development, global markets, industrial developments, and poor waste regulation had affected the quality and quantity of Human or aquatic life.

There are two types of water bodies, namely: surface and underground. Surface water includes oceans, seas, rivers, streams, brooks, lakes and flood. Whereas underground water comprises boreholes and wells. The majority of residents worldwide drink underground water without any form of treatment mainly because of ignorance, and perhaps, lack of access to basic methods of water treatment before usage. Such people can easily contract water-borne diseases such as cholera, and in extreme cases, if care is not taken cancerous diseases.

Water is important for the survival of humanity, a vital resource for all living organisms; the source of life and humans uses water for, domestic, agriculture, economic, transportation and recreational use and many other uses. However, water pollution is a serious issue that is happening in numerous countries including Benin. It is about time we recognized the effects of water pollution, identify its root causes, and find ways to correct the situation to stop pollution at its sources. Water pollution not only affects water quality but also threatens human health, economic development, and social prosperity.

Thus, the development of industries, the intensification of agriculture, and domestic activities introduce chemical substances into the water cycle, a significant part of which reaches lakes, rivers, and groundwater [8]. The quality of finite water resources is under threat from industrial, agricultural, and domestic sources of pollution [9]. Thus, during the last 10 years, the quality of water in the natural environment has seriously been degraded [10].

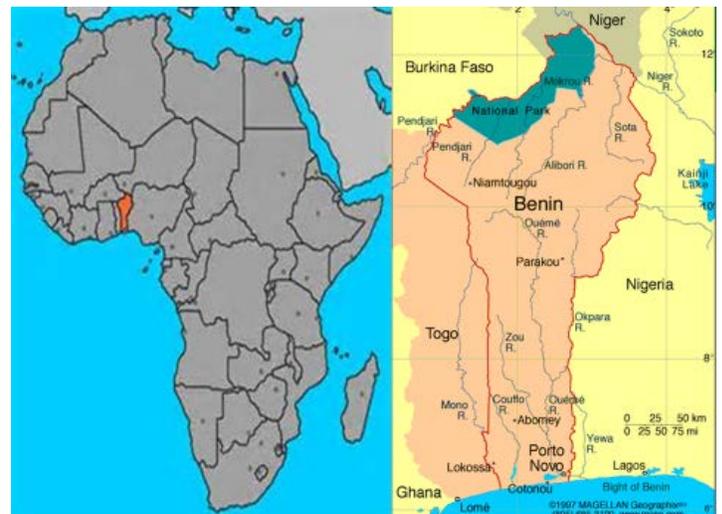
Despite its potentials with 13 billion cubic meters per year and 2 billion cubic meters per year of surface water and groundwater respectively, Benin encounters enormous difficulties in supplying good-quality drinking water [11]. Although Ouémé River is one of the longest and most important in Benin, water supply remains difficult in its catchment area [12]. This situation is accentuated by the use of artificial fertilizers in the cotton zone of the Ouémé Basin, this, directly and indirectly, pollutes the rivers with this basin. [13]. While water supply was the thematic focus of many publications at the global and national level [14, 15, 16, 17], few dealt with water quality. Nowadays, owing to its tremendous significance, the problem of water quality assessment attracts numerous researchers [18]. But according to statistics, 14.7% of the population in Bénin still use rivers, ponds, and swamps as drinking water, even though their water quality remains unknown [19].

The present review paper aims to give some comprehensive ways to improve water resources in Benin based on water pollution problems in Benin, thus based on the effects on health and ecosystems and the control technology.

## II. WATER RESOURCES IN BENIN

Benin is located in West Africa and approximately between latitude 6° and 13° North of the Equator, and between longitudes 0 and 4° east of the Greenwich meridian. It is bordered to the north by the Republics of Niger and Burkina Faso, to the south by the Atlantic Ocean, to the east by the Federal Republic of Nigeria and to the west by the Republic of Togo [20]. The population is more than 10 million, spread unevenly over a national territory of 114,763 km<sup>2</sup> [21]. The largest city and economic capital is Cotonou, which is also the seat of government but the capital of Benin is Porto-Novo [22]. The climate is hot and humid, which affects the quality and quantity of the country's water resources. This results from the influence

of two main rainy and dry seasons per year systems: Annual rainfall in the coastal area averages 1300 mm or about 51 inches. April to late July is the period of the principal rainy season, with a shorter less intense rainy period from late September to November. From December to April is the period of the dry season, with dry wind from the Sahara called the Harmattan, during which a veil of fine dust hangs over the country, the vegetation turns reddish-brown grass dries up and causing the skies to be overcast. Then a short cooler dry season from late July to early September. Humidity and temperatures are high along the tropical coast. Generally, the temperature is between 24 and 31 °C (75.2 and 87.8 °F) [23], although because of the moderating influence of the sea, the mean daily and annual maximum temperatures increase from the coast towards the interior. During the dry season the temperatures are more extreme, ranging between 25 and 31 °C (76 and 87.8 °F). As a tropical nation, Benin is highly dependent on agriculture, with substantial employment and income arising from subsistence farming [24].



*Fig 1: Location map of Benin*

In Benin, water use has not been regulated. Furthermore, water management has been sector-based, fragmented and compartmentalized. To change this, the action was taken to initiate Integrated Water Resources Management (IWRM) in the country. A baseline study was done followed by the drafting of an Integrated Water Resources Management (IWRM) action plan. From that experience, the lesson learned is the advocacy for strengthening political will for supporting the process must be seen as a transversal and on-going action throughout the whole Integrated Water Resources Management (IWRM) process.

The country receives an annual average of 700 mm to 1,300 mm of rainfall from North to South. Rainfall can reach 1,400 mm in the South-Eastern part. Benin is drained by a dense hydrographical network made up of seasonal flow rivers. The renewable water resources of the country are estimated at about 15 billion m<sup>3</sup> of water per year, including approximately 2 billion

and 13 billion m<sup>3</sup> of groundwater and surface water respectively, unequally distributed in space and time.

Nowadays, the country is still at a stage where the catchments and water uses are not controlled and do not fall under any enforced regulation [11].

The country currently uses less than 3% of its renewable water resources, meaning that 97% of the resources are lost through evaporation and spring runoff. According to forecasts established in 2000 (Benin Report, Water Vision 2025) [11], Benin only needs about 40% of its renewable water resources if it is to meet its development needs by 2025, this excluded the non-evaluated needs of the industrial sector. These forecasts, however, do not take into account the impacts of climate change on water resources and the increasingly pressing needs for the populations to adapt.

In addition, the chronic lack of reliable and useful water data and the current mode of GDP calculation make it almost impossible to estimate the real contribution of water to growth and economic development in Benin.

However, the irreplaceable role that water plays in the development of the country was partly taken into account in the 2007-2009 Strategic Document for Growth and Poverty Alleviation (DSCR) as one of the priorities of the Beninese Government [25]. It is true to say that better water resources management is key to growth and economic development in Benin. A draft water law was validated by stakeholders in April 2005 and was submitted to Parliament in July 2007, for its adoption. From a political and legal perspective, the IWRM process enabled Benin to develop a national water policy validated by key stakeholders in January 2008 and adopted by the Government in July 2009. This new water law is the only water-specific regulation which considers the different reforms carried out in the sector in the context of decentralization [26]. It will compensate the obsolete 1987 water law [27].

From an institutional perspective, the water sector in Benin is characterized by multiple decision-making centers, a sector-based coordination, therefore resulting in high economic, social and ecological costs. management framework and a lack of collaboration and dialogue among stakeholders. Management is thus sector-based, fragmented and compartmentalized, with no cross-sectoral

The importance of the availability of high-quality drinking water can be realized by the press release of United Nations Secretary-General on World Water Day 2002. An estimated 2.5 billion people have no access to proper sanitation, 1.1 billion people lack access to safe drinking water, and more than 5 million people die each year from water-related diseases 10 times the number killed in wars, on average, each year. Water is treated all too often as an infinite free good. They are increasingly at risk from pollution and rising demand even where supplies are

sufficient or plentiful. Two-thirds of the world's population is likely to live in countries with moderate or severe water shortages by 2025. Water is an essential element of life. Freshwater comprises 3% of the total water on earth. Only a small percentage (0.01%) of this fresh water is available for human use [28]. Unfortunately, even this small proportion of fresh water is under immense stress due to rapid population growth, urbanization and unsustainable consumption of water in industry and agriculture. According to a United Nations report, the world population is increasing exponentially while the availability of fresh water is declining. Many countries in Africa, Middle East, and South Asia will have serious threats of water shortage in the next two decades. In developing countries, the problem is further aggravated due to the lack of proper management, unavailability of professionals and financial constraint [29].

Water Availability In Benin	Amount (m <sup>3</sup> /person/year)
Renewable freshwater resources per capita (2008)	1,189 <sup>1</sup>
Water withdrawals (2002)	18 <sup>1</sup>
Projected water resources (2015)	948 <sup>2</sup>

**Table 1: Water availability in Benin**

### III. OVERVIEW OF WATER POLLUTION PROBLEM

Today the competition for scarce water resources is intense both in Benin and in many places all over the world. Water pollution is a relatively new problem and increases the stress arising as a result of unprecedented population growth, urbanization, and industrialization since the 1990s [30]. Water pollution problems have become increasingly evident, and have led to serious environmental problems as the urbanization process continues. Industrial production without adequate regard for environmental impacts has increased water and air pollution and has led to soil degradation and large-scale global impacts such as acid rain, global warming, and ozone depletion [31]. But, concurrent investment in management of the water environment has been slower.

Furthermore, water resources development and management have been disorganized, and there is a lack of public

<sup>1</sup> UN Food and Agriculture Organization (FAO). FAO Aquastat Database. "Freshwater resources" refers to estimates of runoff into rivers and recharge of groundwater and does not include flows from other countries.

<sup>2</sup> Note this value was calculated using a straight-line calculation based on average population growth rates (1990-2008) with no adjustment for consumption or technology changes. Data was obtained from World Bank WDI Database (population) and FAO Aquastat Database (water resources).

consciousness for the need for environmental protection and a corresponding lack of legal structures to promote this protection. Water pollution refers to the contamination of freshwater bodies, the only kind of water that humans can drink. It doesn't help that only 2.5 percent of Earth's water is fresh, drinkable water and that most of that are trapped in ice at the poles or deep underground. That leaves about 0.007 percent of Earth's water available for almost seven billion of us to use for drinking, growing food, providing energy, and producing goods.

Water pollution is also defined as the contamination of water bodies such as rivers, oceans, lakes, and groundwater. The water pollution affects living organisms and plants that live in these water bodies and in most cases, all the effect is not only damaging either to individual species and populations but also to the natural biological communities. When pollutants are discharged indirectly or directly into water bodies without adequate treatment to remove harmful constituents, it occurs that water will not be safe for drinking.

In Benin, water pollution occurs in both rural and urban areas. Drinking water from natural sources such as rivers, lakes, and streams in rural areas is usually polluted by organic substances from upstream users who use water for agricultural activities.

When water does not support a human use and either it is impaired by anthropogenic contaminants, like serving as drinking water and undergoes a marked shift in its ability to support its constituent biotic communities, water is referred to as polluted. Algae blooms, storms, and earthquakes are natural phenomena and they are also causing major changes in the ecological status of water and water quality. Water pollution has many causes and characteristics.

For diverse reasons, people are attracted to rivers, lakes, and coastlines. Clean water is a crucial resource for irrigation, transportation, recreation, fishing, drinking, hunting, industry, sheer esthetic enjoyment, and support of biodiversity. Water has been used to dilute pollutants and wash away throughout human history. In recent decades, pollutant inputs have increased and have degraded water quality of many rivers, lakes, and coastal oceans. Degradation of these vital water resources can be measured as the loss of natural systems, their component species, and the amenities that they provide [32, 33]. In the future, water shortages are increasingly common and likely to become more severe [34, 35]. The contamination reduces the supply of water and increases the costs of treating water for use because poor water quality and water shortage are linked. One of the most cost-effective means of increasing water supplies is preventing pollution

#### IV. SOURCES OF WATER POLLUTION IN BENIN

Water pollution is most often due to human activities [36]. The major ones are the indiscriminate disposal of industrial, municipal and domestic wastes in water channels, rivers, streams, and lakes, etc. [37]. An estimated 2 million tons of sewage and other effluents are discharged into the world's waters every day. In developing countries, the situation is worse where over 90% of raw sewage and 70% of untreated industrial wastes are dumped into surface water sources [38]. In Benin, Water pollution is originated from point sources and non-point sources. Sewage treatment plants, manufacturing and agro-based industries and animal farms have been identified as point sources. According to Environment Quality Report of Benin, the Department of Environmental Protection has recorded many water pollution point sources which comprised mainly from manufacturing industries, animal farms and domestic waste, agricultural runoff, and agro-based industries. Agricultural activities and surface runoffs are mainly diffused as Non-point sources.

Today one of the biggest problems facing Benin is water pollution. It cannot be demonstrated, Nonpoint Pollution Sources and the untreated sewage are the most important sources of this form of pollution in Benin. There are other sources of pollution as the runoff from the agricultural sector as well as non-regulated units that belong to small industry. Nonpoint Pollution Sources are considered as the main reason that Benin's lakes, rivers, and estuaries remain polluted according to Benin's Ministry of Environment, Habitat, and Urbanism. Some of the Nonpoint Pollution Sources can be prevented, but much of it is the result of rain and irrigation systems.

Water runoff from farmland, parking lots, industries, pesticides, sewage and other various contaminants into lakes, rivers, water supplies, and eventually the oceans. All the pollutants have a negative, often devastating, impact on aquatic ecosystems and vegetation. Most of the activities that can create Nonpoint Pollution Source include agriculture, animal grazing, septic systems and household product pollution. The Ministry of Energy and Water reports that those activities of mismanagement of potentially harmful pollutants are the key contributing factors to water pollution.

## Cause of Water Pollution



**Fig 2: Sources of water pollution**

In short sum, the main causes of water pollution are man-made. Without thinking about the effects of environmental damage, some greedy human beings are only concerned about profit.

### V. WATER POLLUTION AND HUMAN HEALTH

Water contamination is one of the main causes of health problems in human beings. About 2.3 billion people are suffering from water-related diseases worldwide [39]. In developing countries, more than 2.2 million people die every year due to drinking of unclean water and inadequate sanitation [40]. Water-related infectious and parasitic diseases account for 60% of infant mortality in the world [41].

Researchers have reported connections between water pollution and acute water-borne diseases which include hepatitis, cholera, dysentery, cryptosporidiosis, giardiasis, diarrhea and typhoid [42, 43, 44, 45] and also, the increasingly negative effects of water pollution have put more people at risk of carcinogenic diseases, potentially contributing to cancer villages [46, 47, 48, 49]. Much of what we know about the marginal effects of pollution on health is derived from data reported in developed countries, where pollution levels are relatively low. Compared to developed countries, health risks related to water pollution in developing countries are more serious. About 2.3 billion people in the world are suffering from water-related diseases. Among them, 2.2 billion people live in developing countries [44, 50]. Given the low levels of water pollution in developed countries, these estimates may not be valid in developing countries if there is a nonlinear dose relationship between pollution and health. Moreover, to our best of knowledge, no other study has analyzed the health effects of environmental treatment in Benin.

<sup>3</sup> World Bank. 2009 World Development Indicators (WDI) Database.

<sup>4</sup> World Health Organization (WHO). World Health Statistics 2009.

There are several effects of water pollution in Benin, the most serious being the damage it can do to human health when agricultural pollutants find their way into the local drinking water supply. Certain compounds can cause cancers, and the lesser ailments caused by eating vegetables washed in polluted water and grown with the use of nitrates are dysentery and diarrhea as well as the chance of digesting harmful bacteria which have migrated into the water supply from the farmers' use of animal manure as fertilizer. The effects of using DDT and arsenic-based pesticides and fertilizers are obvious. The general public and agricultural workers are at a great risk when such agricultural pollutants find their way into the human food chain either. Water pollution extensively affects health in humans and aquatic ecosystems. In the long-term, the present level of environmental degradation could create health problems from waterborne diseases for most of this population of Benin. Having to consume unsafe drinking water, many of people are already affected in the country.

### POPULATION AND HEALTH STATISTICS

<b>Population (2008)</b>	<b>8.7 million <sup>(c)</sup></b>
<b>Proportion of population living in urban areas</b>	<b>41%<sup>3</sup></b>
<b>Average annual urban/rural population growth rates (1990-2008)</b>	<b>4.3 /2.7%<sup>3</sup></b>
<b>Under age 5 mortality rate (2007)</b>	<b>123/1000 live births<sup>4</sup></b>
<b>Under age 5 mortality rate due to diarrheal disease (2004)</b>	<b>15.6%<sup>4</sup></b>

**Table 2: Benin population and health statistics**

Industrial effluents and agricultural pesticides accumulate in aquatic environments also causing harm to aquatic animals and lead to biomagnifications. Ecosystems can be also severely affected or damaged by water pollution. Groundwater can also be contaminated by pesticides and fertilizers causing damage to the reproductive system in the wildlife ecosystem. When agricultural run-off and sewage water, that contains organic materials are discharged into fresh water, causes an increase in the growth of algae, in turn, causing oxygen depletion. Water pollution kills the life that inhabits the water-based ecosystem, disrupting the natural food chain.

## VI. WATER POLLUTION CONTROL: MANAGEMENT AND TECHNOLOGY

### A *National environmental policy*

#### i. *Water sector framework*

Benin is revising its national water policy, which includes a strategy for sanitation and hygiene, promotion of Integrated Water Resources Management (IWRM), and creation of a regulatory agency with oversight of water supply and sanitation service provider delivery standards [51]. Responsibility for the water sector lies with the Ministry of Mines, Energy and Hydraulics/Water Resources (MMEE, Ministère des Mines, de l'Énergie et de l'Eau), which initiates, coordinates and regulates water resources activities. Until 2003, responsibility for urban water supply and sanitation was vested in the Benin Water and Electricity Corporation (SBEE). Institutional reform separated the functions of water and electricity supply, and the National Water Company of Benin, (SONEB, Société Nationale des Eaux du Bénin), was established as a semi-autonomous enterprise [51, 52].

SONEB now acts primarily as the public drinking water utility in urban areas. Since December 2003, local councils have been empowered to be the contracting authorities in drinking water supply and distribution, within their respective territories and in accordance with the national policies and regulations [51].

The General Directorate of Water (DG-Eau, Direction Générale de l'Eau) is responsible for overseeing and coordinating drinking water supply in rural areas. At the provincial level, DG-Eau is represented by 11 provincial water divisions. Responsibility is being shifted to the local level, which includes 77 municipalities. In some rural municipalities, user associations play an important role at the local level, though they are generally only involved in the daily management of small facilities, such as hand pumps and piped networks, while DG-Eau plans and implements construction projects [53]. Coordination in the sanitation sub-sector is not as well defined or coordinated as in the drinking water sector [54, 55].

In urban areas, the Directorate of Hygiene and Basic Sanitation which is part of the Ministry of Health (DHAB, Direction Hygiène et Assainissement de Base), shares responsibility for sanitation with SONEB as well as other government directorates [56]. In rural areas, DHAB provides sanitation services to institutions, such as schools, health centers, markets, and government facilities [57, 58].

For economic regulation of the water and sanitation sector, there is no independent agency. The Growth Strategy for National Poverty Reduction, 2007 calls for the establishment of such an authority [59].

#### ii. *Definition and implementation of an IWRM policy*

In Benin, demographic growth will continue to make access and sharing of water resources difficult in both rural and urban areas where the resources are limited and threatened by human activities. Therefore, it is important to define and implement a policy for Integrated Water Resource Management which should intervene at various levels [60]. As is the intermediary level (quantitative and qualitative knowledge and monitoring of the resource), the institutional level (adapting the Water Act and the other current regulations) is important. But it is very important to take action at local level, to develop the joint capacity to protect and share water resources in a sustainable manner, at the level of the commune, at the local or micro-local level, or even at the level of a rural territory.

#### B *Water Resources Management*

The government adopted Integrated Water Resources Management (IWRM) in 1998, as a priority approach for sustainable management of its water resources [61]. The decision was a consequence of the findings of a report on Benin's strategy for water resources management. The report, validated in February 1998, recommended the adoption of IWRM to improve water resources management in the country [60].

Despite important actions implemented between 1998 and 2002, the framework for water resources management in Benin was not in favor of good water governance. Following the 2002 World Summit on Sustainable Development (WSSD) resolution for countries to develop and implement national IWRM action plans as a means to achieve the water-related Millennium Development Goals (MDGs), Benin's Government initiated a programme to develop a National IWRM plan. This was part of the Partnership for Africa's Water Development (PAWDII) programme supported by Netherlands Development Cooperation with facilitation by Global Water Partnership.

Under the leadership of Benin government, the Benin Water Partnership mobilized stakeholders from governmental and non-governmental organizations and civil society to define a roadmap and vision of the planning process towards better water resources management.

Following various information and sensitization workshops, and different studies, a drafting committee made up of national experts, supported by national and international consultants, was set up. Thematic workshops were organized to refine the results of water situation analysis studies. The water resources challenges were prioritized using Water Resources Issues Assessment Methodology (WRIAM) and priority was given to the main technical problems in terms of assessing, managing and using water resources at the basin and national level. Weaknesses of the water resources management framework were also assessed and analyzed. The content of the national IWRM action plan was developed. 54 Actions were defined for immediate and

long-term implementation. A draft IWRM action plan was validated by stakeholders during 6 regional workshops. The IWRM action plan was being finalized in March 2010 and was supposed to be followed by implementation.

### *C Strategies under the National Policy on Environment*

Since 1998, Benin's Government has reaffirmed on several occasions its willingness to operate a transition towards IWRM approach, gradually through various reforms and programs established [60]. Initiatives were undertaken by Benin before the beginning of the Partnership for Africa's Water Development programme (PAWDII, 2005-2009) include:

□ Between 1996 and 1997 a study was conducted on a national strategy for water resources management, which was validated by all stakeholders in February 1998. Benin Government then adopted the conclusions of the study, in particular, the recommendation to take integrated approach to water resources management; [60]

□ Developed dialogue with all stakeholder and with Global Water Partnership's (GWP) support [62], of a long-term national Vision for water resources management by 2025, presented at the 2nd World Water Forum (The Hague, March 2000) [11];

□ Organized the 1st National Water Forum in January 2001;

□ Organized in September 2001 Benin Country Water Partnership's (Benin-CWP) statutory General Assembly; [63]

□ Adoption of the first Budget per Objective Programme by the Ministry of Mines, Energy, and Hydraulics (2002-2005), which stressed the need for a formal dialogue framework in order to guarantee equitable and sustainable management of water resources in accordance with established rules; [64]

□ published a situation analysis report on the legal and institutional framework of the water sector in January 2004.

□ Development of a new strategy for drinking water supply sub-sector in rural area (Strategy AEP 2004-2015) which takes into account IWRM principles and decentralization context, through the preparation of mechanisms to transfer competencies and resources to municipalities; [65]

□ established in September 2004 a Technical Permanent Secretariat for Coordination and Promotion of IWRM (STPC-GIRE) within the proposition of an institutional framework to conduct the reforms towards IWRM: the framework for Promotion and Coordination of IWRM (CPC-GIRE), that Secretariat is hosted by STPC-GIRE. The intermediate objective of the IWRM process is to have a national IWRM action plan, supplemented by a portfolio of investments

## VII. CONCLUSION AND RECOMMENDATION

The conclusions and observations made in this paper point to prioritize areas for action or attention from public health

authorities, environmental policymakers, and research institutions. One of the priorities should be to increase public health objectives within the current management framework. Within the overall framework established by the national Law of Water and the Law of Water Pollution Prevention, the protection of water quality and enforcement of water quality standards are under the Ministry of Energy and Water jurisdiction. Even with these mechanisms in place, change cannot be implemented without comprehensive, continuous, and systematic research on water pollution and related health effects. In particular, this review suggests the need to focus on the following research areas: 1) the prevalence of algal toxins in surface water bodies and their impacts on health; 2) an evaluation of fertilizer and pesticide contamination in ambient and groundwater bodies, as well as identification of exposure routes (bioaccumulation in aquatic organisms and contamination of drinking water sources); 3) research on additive or synergistic effects on health created by the compounded effect of multiple pollutants; 4) monitoring of drinking water quality in conjunction with monitoring of disease morbidity and mortality; and 5) dissemination of research information to regional and local bureaus (environmental and health) to assist with their decision making.

Regular surveys need to be conducted in various parts of the country to obtain a clear picture of water-linked diseases. The following recommendations are made which may help to control or diminish the problems of deteriorating water quality in Benin.

- There should be continuous monitoring of drinking water throughout the country both in rural and urban locations.
- Local authorities should be provided with facilities for monitoring and purification of drinking water.
- There is a need to shift from an intermittent to a continuous water supply system to avoid the widespread contamination caused by intermittent water supply.
- There should be a renovation of old and rusty pipelines of the water distribution network.
- There should be sufficient distances between sewage and drink water supply lines to avoid cross-contamination.
- There is a need for the existence and implementation of strict laws with no compromise on the quality of public drinking water.
- Public awareness campaigns should be launched to educate the population about the importance of safe drinking water.
- The public should receive guidance to adopt safety measures for stored water inside their houses.
- The farming community needs to be educated well about the safe handling and use of pesticides and proper application of fertilizers to minimize the contribution of agricultural practices to water pollution.

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## REFERENCES

- [1] Zakaria L (1992) L'eau source de vie, Thèmes clefs d'Afrique. Encyclopédie Afrique Jeunes. Agence de coopération Culturelle et technique (ACCT),

- [2] Radomskii SM, Radomskaya VI, Matyugina EB, Gusev MN (2007) Basic physicochemical characteristics of the state of upper amur surface water. *Water Resour* 34:60–69
- [3] Ajibade LT (2004) Assessment of water quality along river Asa, Ilorin, Nigeria. *Environmentalist* 24:11–18
- [4] Herschy RW (1999). *Hydrometry Principles* (2nd edition) John Wiley and Sons, Chichester.
- [5] United State Agency for International Development (USAID) (1990). *Strategies for drinking water and sanitation program for child survival*, USAID, Washington, D.C.
- [6] Warner D (1998). *Drinking water supply and environmental sanitation for health*. Presented at the International conference for sustainable development, Paris.
- [7] World Health Organization (WHO) (1997). *Health and Environment in Sustainable Development, five years after the earth summit*. (WHO) Geneva, (WHO/EHG/97.8), p. 245.
- [8] Grosclaude G (1998) *L'eau. Tome II: usages et polluants*. Institut National de la Recherche Agronomique, INRA, Paris, pp 11–15
- [9] Chalk MP (2000) In Bacchi OOS, Reichardt K et Calvache M (eds) *Les sondes à neutrons et à rayons Gamma: leurs applications en agronomie*. International Atomic Energy Agency (AIEA), Vienna
- [10] IFEN(2003) *La qualité de l'eau: une préoccupation environnementale forte*. Données de l'environnement No. 91, Institut Français de l'Environnement. <http://www.ifen.fr/publications/DE/de91.htm>. Accessed 16 June 2010
- [11] DH (2000) *Vision Eau 2025*. Direction Générale de l'Hydraulique, Bénin
- [12] Le Barbé L, Alé G, Millet B, Texier H, Borel Y, Guralde R (1993) *Les ressources en eaux superficielles de la république du Bénin*. ORSTOM, Paris
- [13] Yehouenou-Pazou AE (2005) *Les résidus de pesticides chimiques de synthèse dans les eaux, les sédiments et les espèces aquatiques du bassin versant du fleuve Ouémé et du Lac Nokoué*. Dissertation, Université d'Abomey-Calavi, Bénin.
- [14] Azonnapko OV (2005) *Approvisionnement et Gestion des Ressources en Eau dans la commune de pobè*. Mémoire de maîtrise de Géographie, FLASH. Université Abomey-Calavi, Bénin, p 84
- [15] Fakorédé AIM (2002) *La Gestion des Ressources en Eau par les communautés Rurales de la Sous-préfecture de Ouèssè*. Mémoire de Maîtrise en Géographie. DGAT/FLASH. Université Abomey-Calavi, Bénin
- [16] Marga J (1996) *Les ressources en Eau: conception et évaluation*. Edition BRGM cartographie comptabilité Orléans cedex, France
- [17] Wagner EG, Lanoix JN (1961) *Approvisionnement en Eau des zones Rurales et des Petites gglomérations*. Série de Monographie, vol 42. OMS, Genève.
- [18] Moiseenko TI (2005) *Ecotoxicological approach to water quality assessment*. *Water Resources* 32:163–174
- [19] INSAE (2002) *Recensement Général de la Population et de l'Habitat*. Institut National de la Statistique et de l'Analyse Economique, Cotonou
- [20] Hughes, R. H.; Hughes, J. S. (1992). *A Directory of African Wetlands*. IUCN. p. 301. ISBN 978-2-88032-949-5.
- [21] *Annuaire Statistique 2010 (Report)* (in French). INSAE. 2012. p. 49. Retrieved 17 December 2015.
- [22] *World Population Prospects: The 2017 Revision*". ESA.UN.org (custom data acquired via website). United Nations Department of Economic and Social Affairs, Population Division. Retrieved 10 September 2017.
- [23] *Background Note: Benin*". U.S. Department of State (June 2008). This article incorporates text from this source, which is in the public domain.
- [24] *Food and Agriculture Organization of the United Nations*". United Nations, 29 June 2010
- [25] Ministry of Energy and Water, *Thematic report of SCRP sectoral group on water and sanitation*, 2009, 22 p.
- [26] Ministry of the Interior and Public Security, *Texts of laws on decentralization in Benin*, 1999
- [27] Ministry of Public Health, *Sanitation code*, 1987, 48p
- [28] Hinrichsen D, Tacio H. *The coming freshwater crisis is already here. The linkages between population and water*. Washington, DC: Woodrow Wilson International Center for Scholars; 2002. Retrieved from <http://www.wilsoncenter.org/topics/pubs/popwawa2.pdf>
- [29] PCRWR. *National Water Quality Monitoring Programme. Water Quality Report 2003– 2004*. Islamabad, Pakistan: Pakistan Council for Research in Water Resources (PCRWR; 2005. available at [http://www.pcrwr.gov.pk/wq\\_phase3\\_report/TOC.htm](http://www.pcrwr.gov.pk/wq_phase3_report/TOC.htm).
- [30] Chen, 2002 J. *Chen Analysis of water environment in the Xinjiang arid region* *Arid Environmental Monitoring*, 16 (4) (2002), pp. 223-227
- [31] Seth, 2003 S.M. *Seth Human impacts and management issues in arid and semi-arid regions* I. Simmers (Ed.), *Understanding Water in a Dry Environment – Hydrological Processes in Arid and Semi-arid Zones*, IAHI-ICH 23 (2003) Balkema, Rotterdam, pp. 289–341
- [32] U.S. EPA (U.S. Environmental Protection Agency). 1988. *Quality criteria for water*. EPA 440/5-86-001. USEPA, Office of Water Regulations and Standards. U.S. Government Printing Office (PB81-226759), Washington, D.C., USA.
- [33] Postel, S. L., and S. R. Carpenter. 1997. *Freshwater ecosystem services*. Pages 195–214 in G. C. Daily, editor. *Nature's Services*. Island Press, Washington, D.C., USA.
- [34] Postel, S. L., G. C. Daily, and P. R. Ehrlich. 1996. *Human appropriation of renewable fresh water*. *Science* 271: 785–788.
- [35] Postel, S. L. 1997. *Last Oasis*. Second edition. Island Press, Washington, D.C., USA.
- [36] Hammer MJ. *Water and wastewater technology*. New York, USA: John Wiley Inc.; 1986
- [37] Kahlowan MA, Majeed A. *Water-resources situation in Pakistan: challenges and future strategies*. *Water resources in the south: present scenario and future prospects* Islamabad, Pakistan: Commission on Science and Technology for Sustainable Development in the South (COMSATS); 2003. p. 21–39.
- [38] Anonymous. *World Water Day 22.03.2010; 2010*. Retrieved from [www.worldwaterday2010.info](http://www.worldwaterday2010.info), United Nations.
- [39] UNESCO. *Water for people water for life. The United Nations World Water Development Report; 2003*. United Nations Educational, Scientific and Cultural Organization (UNESCO) and Berghahn Books
- [40] WHO, UNISEF. *Global water supply and sanitation assessment 2000 report*. USA: World Health Organization and United Nations Children's Fund; 2000. Available at: [http://www.who.int/water\\_sanitation\\_health/monitoring/jmp2000.pdf](http://www.who.int/water_sanitation_health/monitoring/jmp2000.pdf)
- [41] Ullah R, Malik RN, Qadir A. *Assessment of groundwater contamination in an industrial city, Sialkot, Pakistan*. *Afr J Environ Sci Technol* 2009; 3:429–46.
- [42] WB-SCEA, 2006 *WB-SCEA Pakistan Strategic Country Environmental Assessment. Main Report (2006)*, pp. 1-66 Report no. 36946-PK World Bank.
- [43] Cutler and Miller, 2005 D.M. Cutler, G. Miller "The role of public health improvements in health advances: the twentieth-century United States Demography, 42 (2005), pp. 1-22
- [44] Jalan and Ravallion, 2003 J. Jalan, M. Ravallion *Does pipe water reduce diarrhea for children in rural India?* *J. Econ.*, 112 (2003), pp. 153-173
- [45] Roushdy et al., 2012 R. Roushdy, M. Sieverding, H. Radwan "The Impact of Water Supply and Sanitation on Child Health: Evidence from Egypt. *New York Population Council, New York* (2012)
- [46] Lin et al., 2000 N.F. Lin, J. Tang, H.S.M. Ismael *Study on environmental etiology of high incidence areas of liver cancer in China* *World J. Gastroenterol.*, 6 (2000), pp. 572-576
- [47] Lu et al., 2015 Y.L. Lu, S. Song, R.S. Wang, Z.Y. Liu, J. Meng, A.J. Sweetman, A. Jenkins, R.C. Ferrier, H. Li, W. Luo, T.Y. Wang *Impacts of soil and water pollution on food safety and health risks in China* *Environ. Int.*, 77 (2015), pp. 5-15
- [48] Morales-Suarez-Varela et al., 1995 M.M. Morales-Suarez-Varela, A. Llopis-Gonzalez, M.L. Tejerizo-Perez "Impact of nitrates in drinking water on cancer mortality in Valencia, Spain *Eur. J. Epidemiol.*, 11 (1995), pp. 15-21
- [49] Ebenstein, 2012 A. Ebenstein "The consequences of industrialization: evidence from water pollution and digestive cancers in China. *Rev. Econ. Statistics*, 94 (2012), pp. 186-201
- [50] Azizullah et al., 2011 A. Azizullah, M.N.K. Khattak, P. Richter, D.P. Häder *Water pollution in Pakistan and its impact on public health — A review* *Environ. Int.*, 37 (2011), pp. 479-497

- [51] Le décret N°2003-203 portant création de la Société Nationale des Eaux du Bénin (SONEB) en République du Bénin
- [52] Danish International Development Agency (DANIDA) (August 2004). "Programme d'Appui au Développement du Secteur Eau et assainissement (PADSEA) (Phase II)". Retrieved 2008-05-16., p. 12-13
- [53] DG-Eau, National water Policy document, 2008
- [54] Direction Générale de l'Hydraulique (2004) stratégie Nationale de l'approvisionnement en Eau potable en milieu rural du Bénin 2004-2015; Cotonou, Bénin.
- [55] Danish International Development Agency (DANIDA) (August 2004). "Programme d'Appui au Développement du Secteur Eau et assainissement (PADSEA) (Phase II)". Retrieved 2008-05-16., p. 23-27
- [56] Ministry of Health, National sanitation policy document of Benin, 1995
- [57] Ministry of Health, National hygiene and sanitation policy document, 2002, 82 p
- [58] Water and Sanitation Program - Africa (December 2006). "Getting Africa on Track to Meet the MDGs on Water and Sanitation". Retrieved 2008-05-16., p. 2-4
- [59] Republic of Benin (April 2007). "Growth Strategy for Poverty Reduction". Retrieved 2008-05-21., p. 37
- [60] Adoption of Integrated Water Resources Management (IWRM) approach (1998) by Benin's Government
- [61] World Health Organization (1998). Guidelines for drinking water: Health criteria and other supporting information. Geneva
- [62] GWP (2004) Catalyzing change: a handbook for developing integrated water resources management (IWRM) and water efficiency strategies.
- [63] CWP-Benin et al, Benin blue book « Water, life, human development », 2008, 90 p
- [64] Ministry of Mines, Energy, and Hydraulics; Adoption of the first Budget Per Objective Programme (2002-2005),
- [65] Direction Générale de l'Hydraulique (2004) stratégie Nationale de l'approvisionnement en Eau potable en milieu rural du Bénin 2004-2015; Cotonou, Bénin.

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